

### SULFIDE-CONTAINING POLYTHIOLS

[0001] The present invention relates to sulfide containing polythiols and methods for their preparation. This application claims priority from a Provisional Patent

5 Application having Serial No. 60/435,537, filed on December 20, 2002.

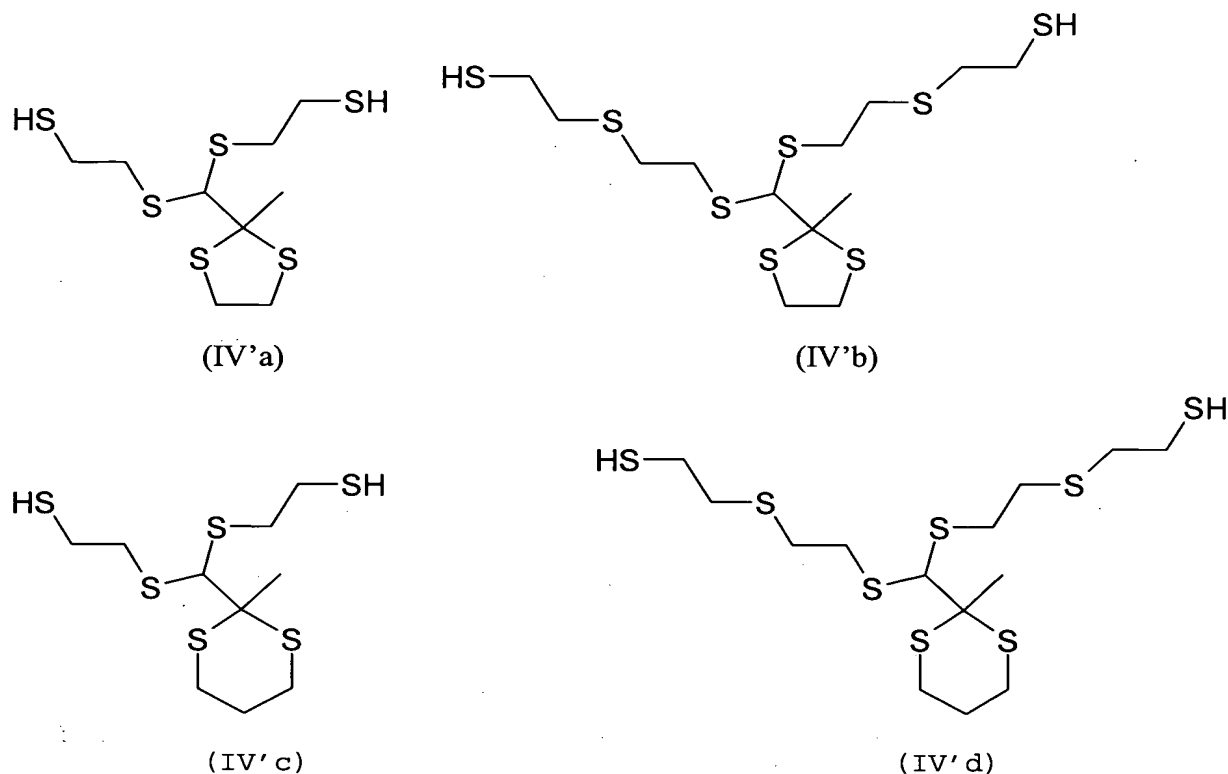
[0002] Sulfide-containing polythiols can have a variety of uses and applications. The sulfide-containing polythiols of the present invention can be especially useful in polyurethane  
10 compositions for the manufacture of ophthalmic lenses.

[0003] For the purposes of this specification, unless otherwise indicated, all numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being  
15 modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At  
20 the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

25 [0004] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contain certain errors necessarily  
30 resulting from the standard deviation found in their respective testing measurements.

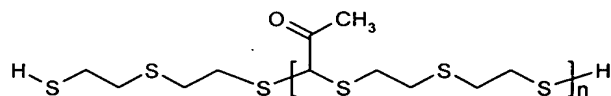
[0005] The present invention provides for a composition comprising one or more sulfide-containing polythiols chosen

from the materials represented by the following structural formulas:



and methods for their preparation.

[0006] The present invention further provides for a composition comprising a sulfide-containing oligomeric polythiol represented by the following structural formula:



wherein  $n$  can represent an integer from 1 to 20, and method for its preparation.

[0007] In a non-limiting embodiment, the sulfide-containing polythiols of the present invention can comprise 1,3-dithiolane and 1,3-dithiane. Non-limiting examples of sulfide-containing polythiols comprising 1,3-dithiolane can include the materials represented by structural formulas IV'a

and b, above. Non-limiting examples of sulfide-containing polythiols comprising 1,3-dithiane can include the materials represented by structural formulas IV'c and d, above.

[0008] The sulfide-containing polythiols comprising 1,3-dithiolane or 1,3-dithiane can be prepared by reacting asym-dichloroacetone with polymercaptan, and then reacting the reaction product with polymercaptoalkylsulfide, polymercaptan or mixtures thereof.

[0009] Non-limiting examples of suitable polymercaptans for use in the reaction with asym-dichloroacetone can include but are not limited to materials represented by the following formula,



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wherein Y can represent  $\text{CH}_2$  or  $(\text{CH}_2-\text{S}-\text{CH}_2)$ , and n can be an integer from 0 to 5. In a non-limiting embodiment, the polymercaptan for reaction with asym-dichloroacetone in the present invention can be chosen from ethanedithiol, propanedithiol, and mixtures thereof.

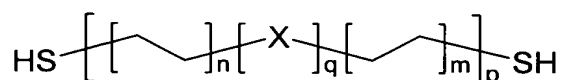
[0010] The amount of asym-dichloroacetone and polymercaptan suitable for carrying out the above reaction can vary. In a non-limiting embodiment, asym-dichloroacetone and polymercaptan can be present in the reaction mixture in an amount such that the molar ratio of dichloroacetone to polymercaptan can be from 1:1 to 1:10.

[0011] Suitable temperatures for reacting asym-dichloroacetone with polymercaptane can vary. In a non-limiting embodiment, the reaction of asym-dichloroacetone with polymercaptane can be carried out at a temperature within the range of from 0 to 100°C.

[0012] Non-limiting examples of suitable polymercaptans for use in the reaction with the reaction product of the asym-

dichloroacetone and polymercaptan, can include but are not limited to materials represented by the above structural formula 1, aromatic polymercaptans, cycloalkyl polymercaptans, heterocyclic polymercaptans, branched polymercaptans, and mixtures thereof.

[0013] Non-limiting examples of suitable polymercaptoalkylsulfides for use in the reaction with the reaction product of the asym-dichloroacetone and polymercaptan, can include but are not limited to materials represented by the following formula,



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wherein X can represent O, S or Se, n can be an integer from 0 to 10, m can be an integer from 0 to 10, p can be an integer from 1 to 10, q can be an integer from 0 to 3, and with the proviso that (m + n) is an integer from 1 to 20.

[0014] Non-limiting examples of suitable polymercaptoalkylsulfides for use in the present invention can include branched polymercaptoalkylsulfides. In a non-limiting embodiment, the polymercaptoalkylsulfide for use in the present invention can be dimercaptoethylsulfide.

[0015] The amount of polymercaptan, polymercaptoalkylsulfide, or mixtures thereof, suitable for reacting with the reaction product of asym-dichloroacetone and polymercaptan, can vary. In a non-limiting embodiment, polymercaptan, polymercaptoalkylsulfide, or a mixture thereof, can be present in the reaction mixture in an amount such that the equivalent ratio of reaction product to polymercaptan, polymercaptoalkylsulfide, or a mixture thereof, can be from 1:1.01 to 1:2. Moreover, suitable temperatures for carrying out this reaction can vary. In a non-limiting embodiment, the

reaction of polymericaptan, polymericaptoalkylsulfide, or a mixture thereof, with the reaction product can be carried out at a temperature within the range of from 0 to 100°C.

[0016] In a non-limiting embodiment, the reaction of asym-  
5 dichloroacetone with polymericaptan can be carried out in the presence of an acid catalyst. The acid catalyst can be selected from a wide variety known in the art, such as but not limited to Lewis acids and Bronsted acids. Non-limiting examples of suitable acid catalysts can include those  
10 described in Ullmann's Encyclopedia of Industrial Chemistry, 5<sup>th</sup> Edition, 1992, Volume A21, pp. 673 to 674. In further alternate non-limiting embodiments, the acid catalyst can be chosen from boron trifluoride etherate, hydrogen chloride, toluenesulfonic acid, and mixtures thereof.

15 [0017] The amount of acid catalyst can vary. In a non-limiting embodiment, a suitable amount of acid catalyst can be from 0.01 to 10 percent by weight of the reaction mixture.

[0018] In another non-limiting embodiment, the reaction  
20 product of asym-dichloroacetone and polymericaptan can be reacted with polymericaptoalkylsulfide, polymericaptan or mixtures thereof, in the presence of a base. The base can be selected from a wide variety known in the art, such as but not limited to Lewis bases and Bronsted bases. Non-limiting examples of suitable bases can include those described in  
25 Ullmann's Encyclopedia of Industrial Chemistry, 5<sup>th</sup> Edition, 1992, Volume A21, pp. 673 to 674. In a further non-limiting embodiment, the base can be sodium hydroxide.

[0019] The amount of base can vary. In a non-limiting  
30 embodiment, a suitable equivalent ratio of base to reaction product of the first reaction, can be from 1:1 to 10:1.

[0020] In another non-limiting embodiment, the preparation of these sulfide-containing polythiols can include the use of a solvent. The solvent can be selected from a wide variety known in the art.

[0021] In a further non-limiting embodiment, the reaction of asym-dichloroacetone with polymercaptan can be carried out in the presence of a solvent. The solvent can be selected from a wide variety of known materials. In a non-limiting  
5 embodiment, the solvent can be selected from but is not limited to organic solvents, including organic inert solvents. Non-limiting examples of suitable solvents can include but are not limited to chloroform, dichloromethane, 1,2-dichloroethane, diethyl ether, benzene, toluene, acetic acid  
10 and mixtures thereof. In still a further embodiment, the reaction of asym-dichloroacetone with polymercaptan can be carried out in the presence of toluene as solvent.

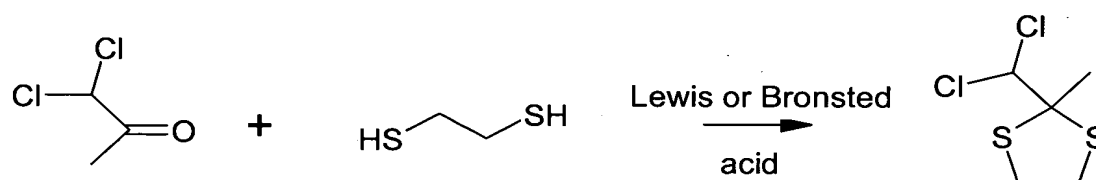
[0022] In another embodiment, the reaction product of asym-dichloroacetone and polymercaptan can be reacted with  
15 polymercaptoalkylsulfide, polymercaptan or mixtures thereof, in the presence of a solvent, wherein the solvent can be selected from but is not limited to organic solvents including organic inert solvents. Non-limiting examples of suitable organic and inert solvents can include alcohols such as but  
20 not limited to methanol, ethanol and propanol; aromatic hydrocarbon solvents such as but not limited to benzene, toluene, xylene; ketones such as but not limited to methyl ethyl ketone; water and mixtures thereof. In a further non-limiting embodiment, this reaction can be carried out in the  
25 presence of a mixture of toluene and water as solvent system. In another non-limiting embodiment, this reaction can be carried out in the presence of ethanol as solvent.

[0023] The amount of solvent can widely vary. In a non-limiting embodiment, a suitable amount of solvent can be from  
30 0 to 99 percent by weight of the reaction mixture. In a further non-limiting embodiment, the reaction can be carried out neat; that is without solvent.

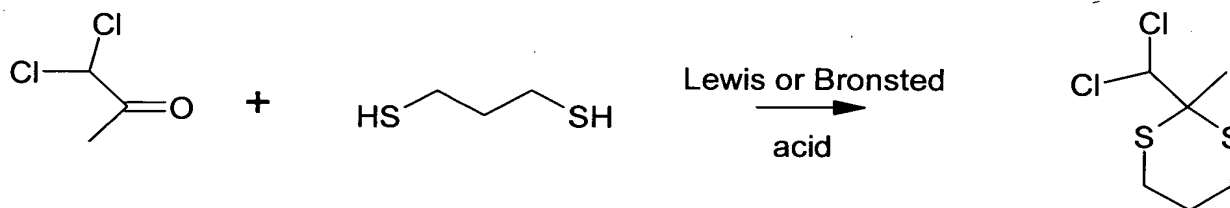
[0024] In another non-limiting embodiment, the reaction of asym-dichloroacetone with polymercaptan can be carried out in

the presence of a dehydrating reagent. The dehydrating reagent can be selected from a wide variety known in the art. Suitable dehydrating reagents for use in this reaction can include but are not limited to magnesium sulfate. The amount of dehydrating reagent can vary widely according to the stoichiometry of the dehydrating reaction.

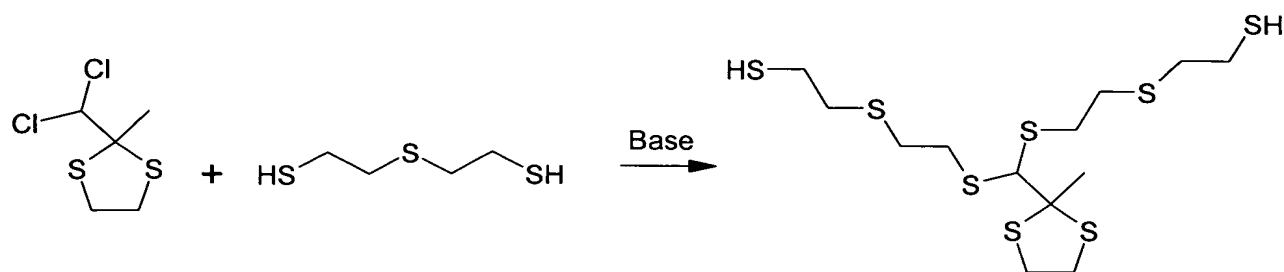
[0025] In a non-limiting embodiment, 1,1-dichloroacetone can be introduced together with 1,2-ethanedithiol in the presence of an acid catalyst to produce 2-methyl-2-dichloromethyl-1,3-dithiolane, as shown below.



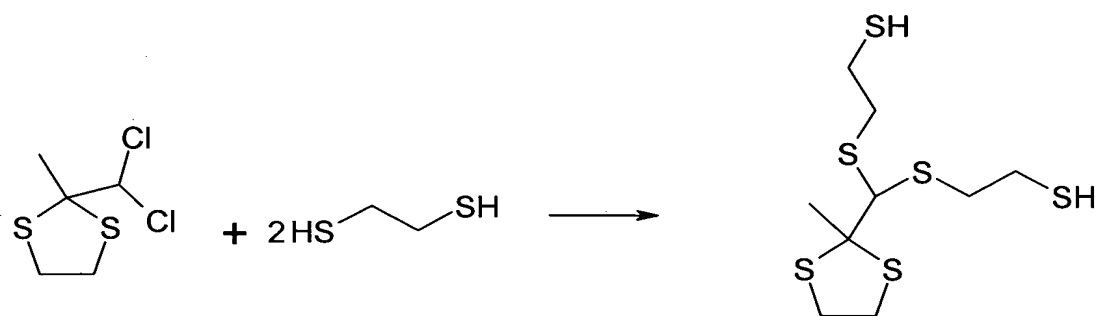
[0026] In a further non-limiting embodiment, 1,1-dichloroacetone can be introduced together with 1,3-propanedithiol in the presence of an acid catalyst to produce 2-methyl-2-dichloromethyl-1,3-dithiane, as shown below.



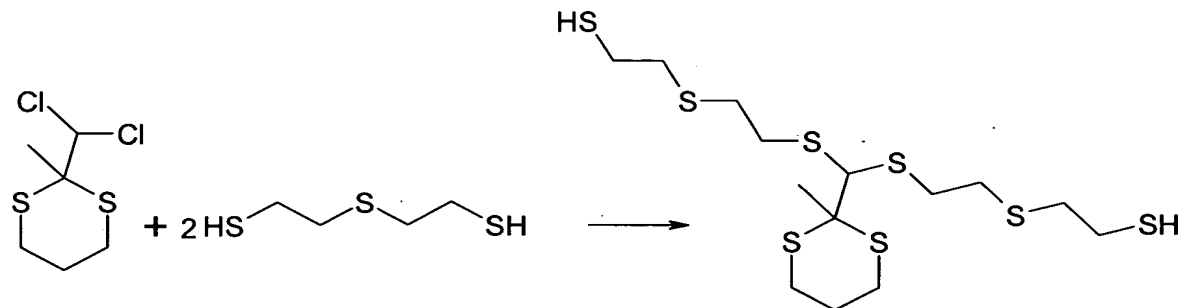
[0027] In another non-limiting embodiment, 2-methyl-2-dichloromethyl-1,3-dithiolane can be introduced together with dimercaptoethylsulfide in the presence of a base to produce a dimercapto 1,3-dithiolane polythiol of the present invention, as shown below.



[0028] In another non-limiting embodiment, 2-methyl-2-dichloromethyl-1,3-dithiolane can be introduced together with  
 5 1,2-ethanedithiol in the presence of a base to produce a dimercapto 1,3-dithiolane polythiol of the present invention, as shown below.



10 [0029] In another non-limiting embodiment, 2-methyl-2-dichloromethyl-1,3-dithiane can be introduced together with dimercaptoethylsulfide in the presence of a base to produce a dimercapto 1,3-dithiane polythiol of the present invention as shown below.

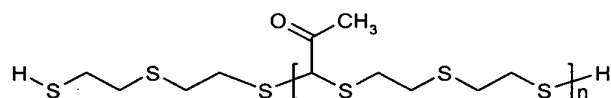


20 [0030] In another non-limiting embodiment, 2-methyl-2-dichloromethyl-1,3-dithiane can be introduced together with





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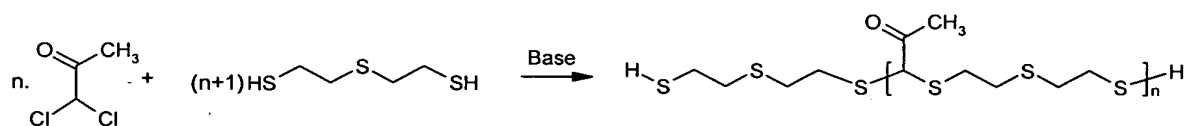
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[0035] In another non-limiting embodiment, the reaction of asym-dichloroacetone with polymercaptoalkylsulfide can be carried out in the presence of a phase transfer catalyst. Suitable phase transfer catalysts for use in the present

invention are known and varied. Non-limiting examples can include but are not limited to tetraalkylammonium salts and tetraalkylphosphonium salts. In a further non-limiting embodiment, this reaction can be carried out in the presence of tetrabutylphosphonium bromide as phase transfer catalyst. The amount of phase transfer catalyst can vary widely. In a non-limiting embodiment, the amount of phase transfer catalyst can be from 0 to 50 equivalent percent, or from 0 to 10 equivalent percent, or from 0 to 5 equivalent percent, to the polymercaptosulfide reactants.

[0036] In another non-limiting embodiment, the preparation of the polythioether oligomeric dithiol of the present invention can include the use of solvent. Non-limiting examples of suitable solvents can include those previously recited herein.

[0037] In a non-limiting embodiment, "n" moles of 1,1-dichloroacetone can be reacted with "n+1" moles of polymercaptoethylsulfide wherein n can represent an integer of from 1 to 20, to produce the polythioether oligomeric dithiol of the invention as follows.



[0038] In a non-limiting embodiment, the polythiols of the present invention can be suitable for optical or ophthalmic applications.

[0039] The invention has been described with reference to non-limiting embodiments. Obvious modifications and alterations can occur to others upon reading and understanding the detailed description.

### EXAMPLES

**Example 1 - Synthesis of 2-Methyl-2-Dichloromethyl-1,3-Dithiolane**

[0040] In a three-necked flask equipped with a magnetic stirrer and having a nitrogen blanket at the inlet and outlet, were added 13.27 grams (0.106 mole) of 1,1-dichloroacetone, 11.23 grams (0.119 mole) of 1,2-ethanedithiol, 20 grams of anhydrous MgSO<sub>4</sub>, and 5 grams of Montmorillonite K-10 (obtained from Aldrich Chemical) in 200 ml of toluene. This reaction mixture was stirred for 24 hours at room temperature. The insoluble material was filtered off and the toluene was evaporated under vacuum using a Buchi Rotaevaporator, to provide 17.2 grams (80% yield) of 2-methyl-2-dichloromethyl-1,3-dithiolane. The product was then vacuum distilled at a temperature within the range of from 102 to 112°C, at a pressure of 12 mm Hg. An NMR analysis was then conducted using Varian Unity Plus Machine. The NMR results are as follows: <sup>1</sup>H NMR (CDCl<sub>3</sub>, 200 MHz): 5.93 (s, 1H); 3.34 (s, 4H); 2.02 (s, 3H); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 50 MHz): 80.57; 40.98; 25.67.

**Example 2 (PAPER EXAMPLE ONLY; EXAMPLE WAS NOT ACTUALLY CONDUCTED) - Synthesis of 2-Methyl-2-Dichloromethyl-1,3-Dithiane**

[0041] In a three-necked flask equipped with a magnetic stirrer and having a nitrogen blanket at the inlet and outlet, are added 13.97 grams (0.11 mole) of 1,1-dichloroacetone, 10.8 grams (0.10 mole) of 1,3-propanedithiol and 50 milliliters of chloroform. The reaction mixture is cooled to 0°C. A slow stream of hydrogen chloride gas is then bubbled through the solution for approximately five minutes. Upon the reaction mixture reaching saturation, the mixture is allowed to set at room temperature for approximately thirty minutes. The solvent is then evaporated and a crude 2-methyl-2-dichloromethyl-1,3-dithiane derivative is expected in a yield of approximately 80-90%.

Example 3 (PAPER EXAMPLE ONLY; EXAMPLE WAS NOT ACTUALLY CONDUCTED) -  
Reaction of 2-Methyl-2-Dichloromethyl-1,3-Dithiolane with 2-  
Mercaptoethyl Sulfide

[0042] In a three-necked flask equipped with a magnetic  
5 stirrer and having a nitrogen blanket at the inlet and outlet,  
is added 20.30 grams (0.1 mole) of 2-methyl-2-dichloromethyl-  
1,3-dithiolane, 30.86 grams (0.2 mole) of 2-  
mercaptoethylsulfide, and 100 milliliters of ethanol. The 2-  
methyl-2-dichloromethyl-1,3-dithiolane is prepared as  
10 described in Example 1 above. To this reaction mixture is  
added dropwise 16.3 grams (0.2 mol) of 49% sodium hydroxide  
(NaOH) at a temperature of from 35-40°C. The temperature is  
then raised to 50°C and the reaction mixture is allowed to set  
at 50°C for two hours. The mixture is then cooled to room  
15 temperature and the precipitated sodium chloride (NaCl) is  
removed by filtration. The ethanol and water are evaporated  
under vacuum to obtain the dimercapto polysulfide in an  
expected yield of approximately 60-70%.

20 Example 4 - Synthesis of Oligomeric Polythioether Dithiol (PTE  
Dithiol 1) wherein n=1

[0043] Dissolved in 350 ml of H<sub>2</sub>O was 44.15 grams (1.01 mol)  
of NaOH. This solution was cooled to room temperature, and  
500 ml of toluene was added, followed by the addition of  
25 159.70 grams (1.04 mol) of dimercaptoethylsulfide. The  
mixture was warmed to 40°C, stirred and cooled to room  
temperature. Added drop-wise to the mixture was 66.35 grams  
(0.52 mol) of 1,1-dichloroacetone dissolved in 250 ml of  
toluene. The mixture was stirred for an additional 20 hours  
30 at room temperature. The temperature of the mixture was  
maintained between 20-25°C. The organic phase was separated,  
washed with 2 X 100 ml of H<sub>2</sub>O, 1 X 100 ml of brine and dried  
over anhydrous MgSO<sub>4</sub>. The drying agent was filtered off and  
toluene was evaporated using a Buchi Rotaevaporator. The hazy

residue was filtered through Celite to produce 182 grams (i.e., 96% yield) of PTE Dithiol, as a colorless clear oily liquid.

[0044] A Mass Spectra was conducted on a product sample using a Mariner Bio Systems apparatus. The results were as follows: ESI-MS: 385 (M + Na). Therefore, the molecular weight was 362.

[0045] A NMR was conducted on a product sample using a Varian Unity Plus machine. The results were as follows:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 200 MHz): 4.56 (s, 1H), 2.75 (m, 16 H), 2.38 (s, 3H), 1.75 (m, 1.5H).

[0046] The SH groups within the product were determined using the following procedure. A sample size (0.1 mg) of the product was combined with 50 mL of tetrahydrofuran (THF)/propylene glycol (80/20) and stirred at room temperature until the sample was substantially dissolved. While stirring, 25.0 mL of 0.1 N iodine solution (which was commercially obtained from Aldrich 31, 8898-1) was added to the mixture and then allowed to react for a time period of from 5 to 10 minutes. To this mixture was added 2.0 mL concentrated HCl. The mixture was then titrated potentiometrically with 0.1 N sodium thiosulfate in the millivolt (mV) mode. A blank value was initially obtained by titrating 25.0 mL of iodine (including 1 mL of concentrated hydrochloric acid) with sodium thiosulfate in the same manner as conducted with the product sample.

$$\% \text{SH} = \frac{\text{mLsBlank} - \text{mLSSample}}{\text{sample weight, g}} (\text{Normality Na}_2\text{S}_2\text{O}_3) (3.307)$$

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The following results were obtained: 13.4% SH

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[0047] The refractive index (e-line) and the Abbe number were measured using a multiple wavelength Abbe Refractometer Model No. DR-M2, manufactured by ATAGO Co., Limited, in accordance with ASTM 542-00. The refractive index was 1.618 (20°C) and the Abbe number was 35.

Example 5 - Synthesis of Oligomeric Polythioether Dithiol (PTE Dithiol 2) wherein n=3

[0048] NaOH (23.4 g, 0.58 mol) was dissolved in 54 ml of H<sub>2</sub>O. The solution was cooled down to room temperature and dimercaptoethylsulfide (30.8 g, 0.20 mol) was added. Upon stirring the mixture, dichloroacetone (19.0 g, 0.15 mol) was added dropwise while the temperature was maintained at from 20-25°C. After the addition of dichloroacetone was completed, the mixture was stirred for an additional 2 hours at room temperature. The mixture was acidified with 10% HCl to a pH<9, and 100 ml of dichloromethane were then added, and the mixture was stirred. Following phase separation, the organic phase was washed with 100 ml of H<sub>2</sub>O, and dried over anhydrous MgSO<sub>4</sub>. The drying agent was filtered off and the solvent was evaporated using a Buchi Rotaevaporator, which provided 35 grams, (90%) of viscous, transparent liquid having a viscosity (73°C) of 38 cP. The refractive index, Abbe number and SH groups were measured as recited in Example 4 to provide the following results: refractive index (e-line) of 1.622 (20°C), Abbe number of 36, SH group analysis of 8.10%.